

Serial Assessment of Corticomotor Pathway Continuity and Upper Extremity Recovery in Subacute Stroke: A Preliminary Study

Navan Chevasutho¹, Poramed Chayaratanasin¹ , Peerada Eurchedkul^{1*} 

¹ Department of Rehabilitation Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Abstract

Background: Upper extremity weakness is common after stroke and significantly affects functional independence. Transcranial magnetic stimulation (TMS) has been used to assess corticomotor pathway integrity and predict motor recovery, but evidence in the subacute phase remains limited.

Objectives: To use serial TMS to examine corticomotor pathway continuity and its association with upper extremity recovery in patients with early subacute stroke and impaired hand function.

Methods: In this preliminary prospective cohort, patients 1 to 6 months after first-ever stroke with upper extremity impairment (Fugl-Meyer Assessment for Upper Extremity [FMA-UE] ≤ 53) underwent serial single-pulse TMS using the visual observation of movement method with a parabolic coil. Motor response (MR) presence and motor threshold were recorded bilaterally, with contralesional stimulation of the affected hand when the ipsilesional MR was absent. The primary outcome was the FMA-UE. Secondary outcomes included the Shoulder Abduction and Finger Extension score, Box and Block Test, Barthel Index, spasticity, and muscle strength. Assessments were performed between 1 and 6 months poststroke.

Results: Seven participants were enrolled (5 completed at least 2 follow-ups). Ipsilesional MR presence was not associated with FMA-UE. Three of 4 initially MR-absent participants showed late MR appearance at approximately 4 to 5 months poststroke, 2 of whom achieved clinically meaningful motor improvement. One participant who remained ipsilesionally MR-absent showed a contralesional response at 6 months. Across the cohort, Barthel Index scores improved in all participants, while muscle strength and spasticity remained relatively stable despite variable motor recovery.

Conclusions: Early subacute corticomotor pathway continuity was not clearly associated with upper extremity recovery, and the early absence of a MR should not be used to limit rehabilitation. Serial assessment revealed late reemergence of corticomotor responses, suggesting that subacute corticomotor continuity is dynamic rather than fixed. Rather than a large cross-sectional correlation study, future work should use serial, electromyography-based TMS within individual patients to track whether the MR or functional performance plateaus first, supporting progress monitoring and realistic expectation-setting.

Keywords: Subacute stroke, Corticomotor pathway continuity, Transcranial magnetic stimulation, Upper extremity recovery, Serial assessment

Citation: Chevasuth N, Chayaratanasin P, Eurchedkul P. Serial assessment of corticomotor pathway continuity and upper extremity recovery in subacute stroke: a preliminary study. *Res Med J*. 20XX;XX(X):e279665. doi:10.33165/rmj.2027.e279665

*** Corresponding Author:**
peerada.eur@mahidol.ac.th

Received: 2 January 2026

Revised: 9 July 2026

Accepted: 5 August 2026

Published Online:
21 August 2026



Copyright © 2026
by the Author(s).

Licensee RMJ. This article is licensed
under the Creative Commons
Attribution (CC BY) License.

Introduction

Stroke is a major cause of disability in Thailand, where approximately 69% of survivors experience upper extremity weakness that impairs quality of life.¹ Most neurological recovery occurs within the first 3 months after stroke, with slower gains thereafter,² and rehabilitation during the subacute phase supports this recovery by promoting neuroplasticity.³

Transcranial magnetic stimulation (TMS) is widely studied for prognosis after stroke. A motor response (MR), or motor evoked potential (MEP), indicates preserved continuity of the corticomotor pathway, and MR presence, larger amplitude, lower resting motor threshold (MT), and a lower interhemispheric threshold ratio have been associated with better motor outcomes.⁴⁻⁷ Biomarker-based models applied within the first days predict 3-month outcomes with high accuracy.⁸

Notably, predictive accuracy appears to decline when TMS is performed later, in the subacute phase, rather than in the first days after stroke.^{9, 10} Researchers suggest that this reflects what TMS measures at each time point. Soon after the insult, MR status may reflect the corticospinal output that survived injury, which is a relatively static estimate of how severely the motor system was disrupted and therefore a substrate for prognosis. In the subacute and chronic phases, the corticomotor response is increasingly shaped by reorganization as the system attempts to reestablish drive to the paretic limb, so that MR status in the early subacute phase may reflect an evolving process rather than a fixed surviving substrate.¹¹ However, poststroke neuroplasticity is not always beneficial for functional recovery. Possibly for this reason, MR status in the subacute phase does not correlate as strongly with functional recovery as MR status in the acute phase of stroke.

Such reorganization need not be confined to the perilesional primary motor cortex. Corticospinal projections arise from a cortical territory wider than the precentral strip, including the premotor and supplementary motor areas and the somatosensory and posterior parietal cortices,¹² and contralesional pathways may also contribute to the drive of the paretic hand.¹¹ Recruitment distributed across these sources, or across hemispheres, may not be reliably elicited by focal stimulation over the primary motor cortex hand hotspot and may appear only gradually. Yet most TMS studies stimulate with a focal figure-of-8 coil and report quantitative parameters that can be derived only in MR-positive patients.⁴ The most severely affected, MR-absent patients are therefore underrepresented, and early MR absence is often treated as a fixed deficit. A broad-field parabolic coil, applied serially and including contralesional stimulation of the affected hand, may be better suited to detecting a distributed or late-emerging response in this population.

The type of rehabilitation may also influence where such reorganization occurs. In this setting, occupational therapy routinely incorporates Cognitive Sensory Motor Training Therapy (the Perfetti method), a sensory-led approach in which patients relearn joint position sense, initially in a single joint and degree of freedom, progressing to complex multiple-joint perception and to perception-guided movement through closed-eye object exploration.¹³ Because somatosensory and posterior parietal cortices contribute to the corticospinal tract,¹² sensory-driven motor practice offers a plausible route by which corticomotor drive to the paretic hand might be reestablished over time.

The motor evoked response to TMS, which is the marker of corticomotor continuity, can be judged by surface electromyography (to detect MEPs) or by a visual observational method. While surface electromyography provides higher sensitivity, its requirement for specialized equipment and longer preparation times often limits its routine clinical application. Therefore, the visual observational method was selected for this study due to

its high feasibility in pragmatic practice. Previous literature has demonstrated that this observation of movement method possesses acceptable reliability and reproducibility for determining MTs,¹⁴ and it was used here with a parabolic coil for which normative values are available.¹⁵ Previous reports on TMS in the subacute period (1 to 6 months) remain limited. This is the stage at which most Thai stroke patients are referred for and can access rehabilitation. Within this window, researchers observed that some patients with no hand function early after stroke nevertheless achieved substantial upper extremity recovery, a trajectory not anticipated by an early absent MR. This clinical observation, together with the limited subacute evidence, prompted the present study.

As a preliminary study, this study enrolled subacute stroke patients (1 to 6 months) with impaired hand function, including those without a MR, to examine whether subacute corticomotor pathway continuity assessed by serial observational TMS is associated with upper extremity recovery and whether corticomotor responses reemerge across the subacute-to-chronic transition and whether such emergence accompanies recovery in patients who initially lacked hand function.

Methods

Study Design and Participants

This was a prospective cohort study conducted at the Department of Rehabilitation Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University. Ethical approval for the study was granted by the Committee for Research of the Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand. Written informed consent was obtained from all participants prior to enrollment.

Adults aged ≥ 18 years who were 1-3 months (early subacute phase) after a first-ever stroke and presented with impaired upper extremity motor function (Fugl-Meyer Assessment for Upper Extremity [FMA-UE] ≤ 53)¹⁶ were included. The exclusion criteria were bilateral weakness; contraindications to TMS (eg, metal implants, cochlear implants, epilepsy, pregnancy); severe upper extremity pain (visual analog scale [VAS] ≥ 7); clinical presentation of distal upper extremity entrapment neuropathy; other neurological disorders such as brain tumor, aneurysm, or Parkinson disease; and unstable medical conditions.

Intervention

Single-pulse biphasic TMS (MagPro R30, MagVenture, Denmark) was applied to the ipsilesional and contralesional primary motor cortices using a parabolic coil. Stimulation began at 30% maximal stimulator output (MSO) and increased in 5% increments. Corticomotor continuity was assessed using the observational movement method.¹⁴ Visible finger or thumb movement was taken as evidence of MR presence. MR absence was defined as no observable movement at intensities up to 60% MSO. To optimize the detection of the MR, particularly in severely impaired patients, This study encouraged participants to perform either active contraction of the target muscle (eg, finger or thumb flexion/extension) or motor imagery of the movement during TMS delivery, as these techniques are known to enhance cortical excitability and facilitate response detection.^{4, 8} MT was defined as the lowest MSO that produced visible movement in ≥ 5 of 10 trials.^{14, 15} Assessments comprised ipsilesional MR/MT for the affected hand and contralesional MR/MT for the unaffected hand, and when the ipsilesional MR was absent, contralesional stimulation of the affected hand was also performed. TMS was performed

serially between 1 and 6 months poststroke. The first follow-up examination was performed 3 months after the first assessment. Some subjects received more than one follow-up examination.

Rehabilitation

All participants underwent usual care rehabilitation as determined by the attending physician. Rehabilitation was delivered as usual care and was not standardized across study participants. Alongside conventional rehabilitation, patients also received, if indicated, robotic-assisted therapy, repetitive transcranial magnetic stimulation (rTMS), and repetitive peripheral magnetic stimulation (rPMS). In the department where this study was conducted, occupational therapy routinely incorporates Cognitive Sensory Motor Training Therapy (the Perfetti method), which is a sensory-led motor retraining approach emphasizing the retraining of joint position sense and perception-guided movement.¹³

Outcome Measures

The primary outcome was the FMA-UE. Secondary outcomes were the Shoulder Abduction and Finger Extension (SAFE) score, spasticity assessed using the Modified Ashworth Scale (MAS), gross manual dexterity assessed using the Box and Block Test (BBT),¹⁷ functional independence assessed using the Barthel Index (BI),¹⁸ and muscle strength assessed using the Medical Research Council (MRC) score, together with MR and MT. Baseline data included age, sex, body mass index, comorbidities, smoking status, lesion side, hand dominance, National Institutes of Health Stroke Scale (NIHSS) score, poststroke duration, poststroke complications, and rehabilitation services and interventions received. All outcomes were assessed between 1 and 6 months poststroke.

Sample Size Calculation

A full-scale study was designed to accommodate at least 8 variables expected to influence poststroke motor recovery (age, lesion side, BI, MR, aerobic exercise, functional electrical stimulation, rTMS, and robotic therapy). Applying 10 participants per variable and allowing for 20% attrition, a target of 96 participants was set. The present report is a preliminary analysis of the participants recruited to date.

Statistical Analysis

Data were analyzed using Stata, version 18.0 (StataCorp LLC). Given the preliminary nature and small sample size of this cohort, findings are reported descriptively. Continuous variables are expressed as medians and ranges, while categorical variables are presented as frequencies and percentages.

Results

During the study period, recruitment was primarily limited by the strict eligibility criteria, specifically the requirement for a first-ever stroke within the narrow early subacute window, combined with specific motor impairment levels and the strict absence of TMS contraindications. Ultimately, only 7 patients who met all the criteria were identified, and all 7 patients were enrolled in the study (no refusals). Of these 7 enrolled participants, 5 completed at least 2 follow-up assessments and were included in the final analysis. At baseline, one participant (Participant 5) demonstrated ipsilesional MR presence, and

4 (Participants 1 to 4) were MR-absent. Baseline demographic and clinical characteristics were determined (Table 1).

Although the inclusion criterion was an FMA-UE score of ≤ 53 , the realized cohort was substantially more impaired. The average baseline FMA-UE score was approximately 18 points and the average BBT score was 0. This indicates moderate-to-severe paresis with no functional use of the hand, even though the MRC score showed some active finger flexion in some cases and some active finger extension in others.

Table 1. Baseline Characteristics of Participants

Characteristic	No. (%)	
	MR-Absent (n = 4)	MR-Present (n = 1)
Age, median (range), y	57 (45-77)	50
BMI, median (range), kg/m ²	29.3 (19.7-39.9)	20.6
Sex		
Male	4 (100)	1 (100)
Female	0	0
Underlying diseases		
Diabetes mellitus	0	0
Hypertension	2 (50)	0
Dyslipidemia	1 (25)	0
Depression	0	0
None	1 (25)	1 (100)
Lesion side		
Right	0	1 (100)
Left	4 (100)	0
Dominant hand		
Right	4 (100)	1 (100)
Left	0	0
Affected dominant hand	4 (100)	0
Aphasia	0	0
NIHSS, median (range)	9 (6-11)	14
Poststroke duration, median (range), d	51.5 (33-83)	47
FMA-UE, median (range)	18.5 (14-38)	18
BBT, median (range)	0	0
BI, median (range)	60 (5-85)	70
MT, median (range)		
Ipsilesional MT to affected hand	NA	37
Contralesional MT to unaffected hand	35 (31-46)	31
SAFE score, median (range)	3 (1-5)	2
Muscle power, assessed by MRC		
Finger flexion	1 (0-1)	1
Finger extension	1 (0-3)	0

Table 1. Baseline Characteristics of Participants (Continued)

Characteristic	No. (%)	
	MR-Absent (n = 4)	MR-Present (n = 1)
MAS, median (range)	1 (1 to 1+)	2
Types of rehabilitation (sessions), median (range)		
Inpatient-based	8.5 (0-12)	0
Outpatient-based	1 (0-2)	0
Telemedicine	0 (0-4)	0
Rehabilitation interventions (sessions), median (range)		
Conventional rehabilitation	12 (2-39)	40
Robotic rehabilitation	0 (0-16)	0
rTMS	0 (0-4)	0
rPMS	5 (0-12)	0

Abbreviations: BBT, Box and Block Test; BI, Barthel Index; BMI, body mass index; FMA-UE, Fugl-Meyer Assessment for Upper Extremity; MAS, Modified Ashworth Scale; MRC, Medical Research Council; MT, motor threshold; NA, not applicable; NIHSS, National Institutes of Health Stroke Scale; rPMS, repetitive peripheral magnetic stimulation; rTMS, repetitive transcranial magnetic stimulation; SAFE, Shoulder Abduction and Finger Extension.

Subacute Motor Response Status and Upper Extremity Recovery

In this preliminary cohort, subacute ipsilesional MR presence did not show a clear pattern or relationship with baseline or subsequent FMA-UE scores. Similarly, contralesional MT to the unaffected hand did not exhibit any consistent trend with upper extremity motor function. Notably, the single participant who demonstrated baseline MR presence (Participant 5) presented with a hemorrhagic stroke and the highest initial stroke severity (NIHSS of 14). This participant showed minimal functional change over time, with the FMA-UE score increasing only slightly from 18 to 19.

Late Emergence of the Motor Response

Among the 4 participants who were MR-absent at baseline, 3 (Participants 1, 2, and 4) transitioned from MR absence to MR presence at approximately 4 to 5 months poststroke (Table 2).

The remaining participant (Participant 3) received the first TMS at 3 months and a further TMS at 6 months poststroke, both showing an absent response in the affected hand during ipsilesional brain stimulation. In this case, however, contralesional brain stimulation produced a MR at 6 months but not at 3 months poststroke. Contralesional MT to the unaffected hand showed no meaningful change over time in any participant (Figure 1).

Functional Trajectories

Two of the 3 participants with late MR emergence (Participants 1 and 4) showed clear, clinically meaningful improvement, each with an FMA-UE increase of ≥ 4 points (Participant 1, 23 to 64 and Participant 4, 38 to 56), together with gains in BBT and SAFE scores (Figures 2, 3, and 4). These 2 participants were the youngest in the cohort (ages 45 and 46) and had both received robotic-assisted therapy and rTMS before the second follow-up. The remaining participants (Participants 2, 3, and 5) showed limited change across FMA-UE, BBT, and SAFE scores. Participant 3, who remained ipsilesionally MR-absent,

consistently had the lowest FMA-UE, BBT, and BI scores (Figures 2, 3, and 5). Spasticity of the affected upper extremity remained stable throughout follow-up (Figure 6). Despite variable motor recovery, all participants improved on the BI (Figure 5).

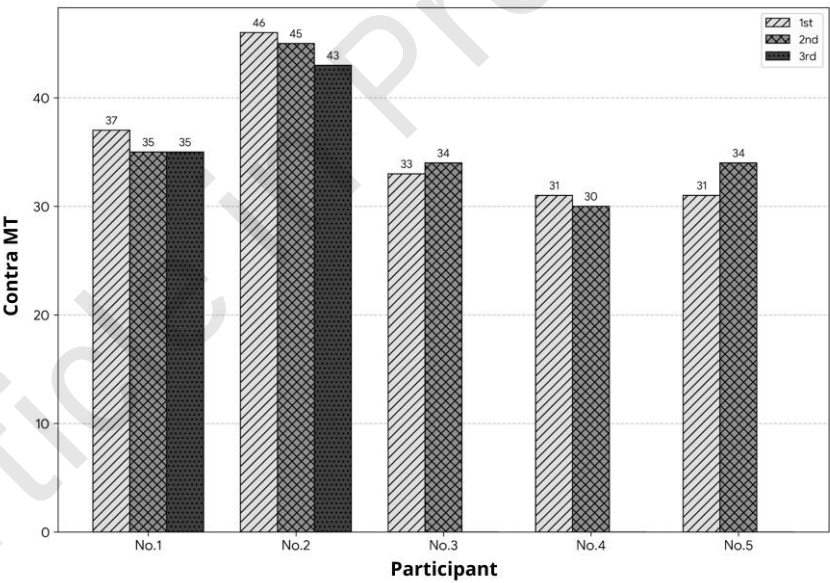
Table 2. Motor Response During Ipsilesional Stimulation of the Affected Hand

Participant	Month of Poststroke					
	1	2	3	4	5	6
1	Absence	NA	NA	Presence	NA	Presence
2	NA	Absence	NA	NA	Presence	Presence
3*	NA	NA	Absence	NA	NA	Absence
4	Absence	NA	NA	Presence	NA	NA
5	Presence	NA	NA	Presence	NA	NA

Abbreviation: NA, not applicable.

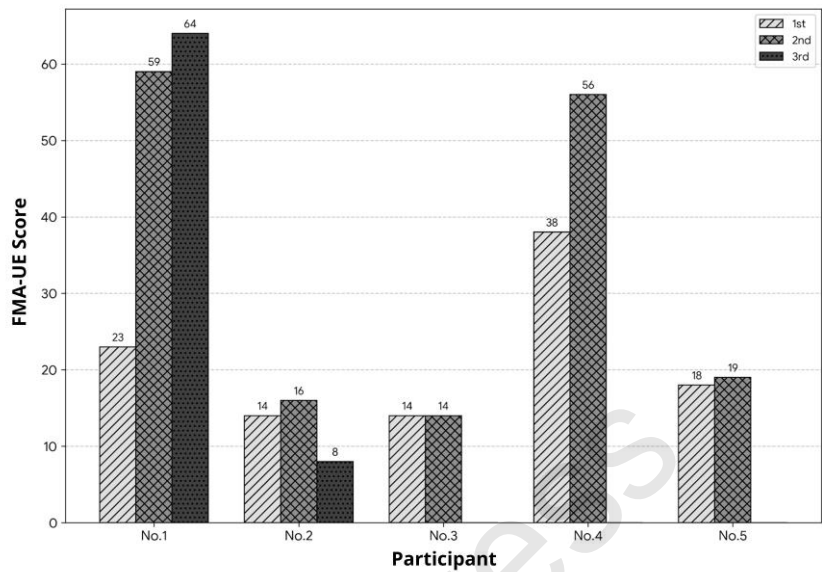
* The motor response (MR) during contralesional stimulation of the affected hand was present at the 6th month.

Figure 1. Contralesional Motor Threshold to the Unaffected Hand



Abbreviation: MT, motor threshold.

Figure 2. Upper Extremity Motor Recovery Assessed by the Fugl-Meyer Assessment for Upper Extremity



Abbreviation: FMA-UE, Fugl-Meyer Assessment for Upper Extremity.

Figure 3. Gross Manual Dexterity Assessed by the Box and Block Test

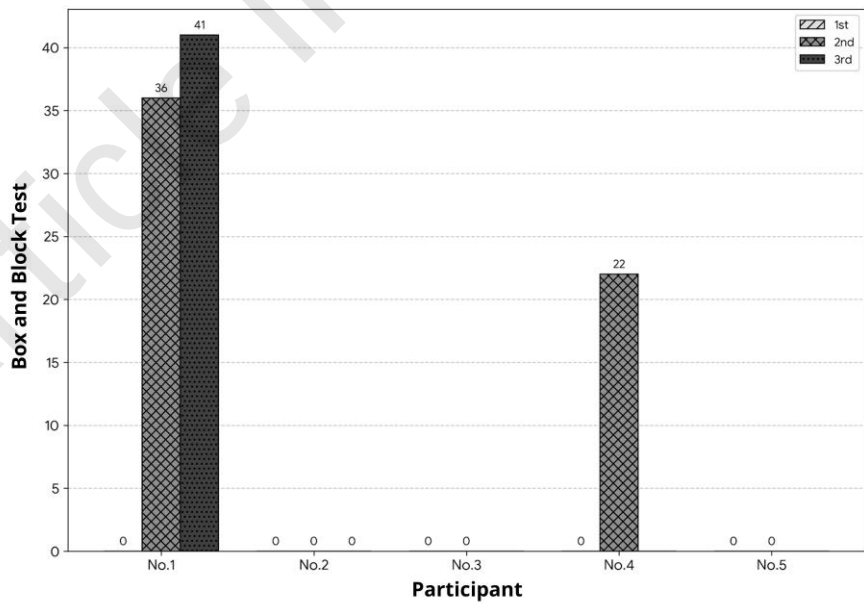
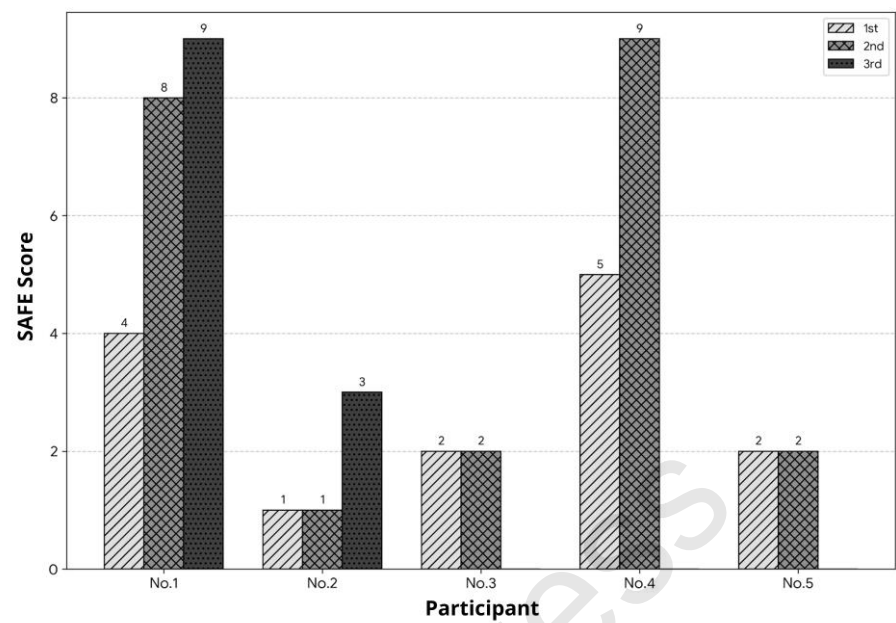


Figure 4. Shoulder Abduction and Finger Extension Scores



Abbreviation: SAFE, Shoulder Abduction and Finger Extension.

Figure 5. Functional Independence Assessed by the Barthel Index

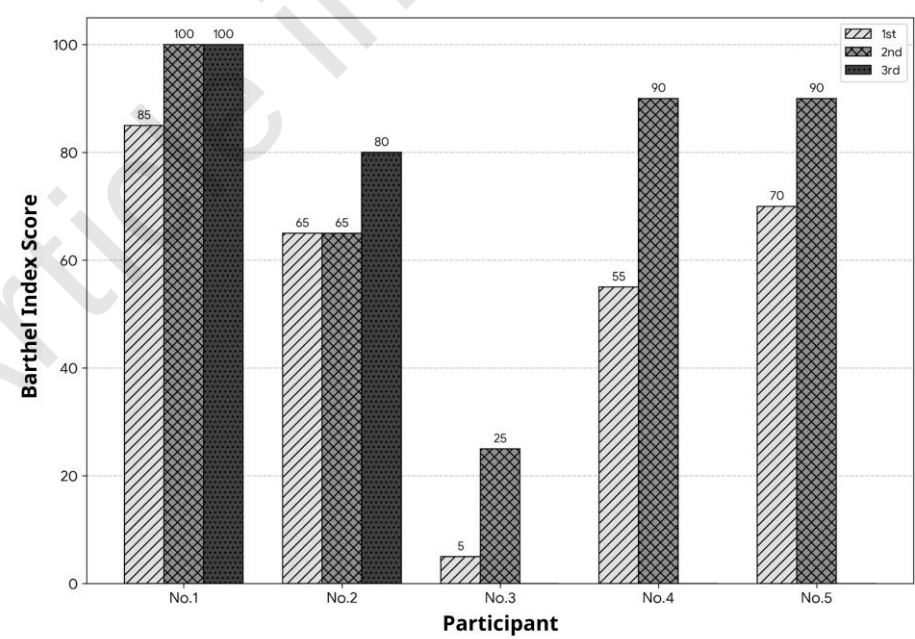
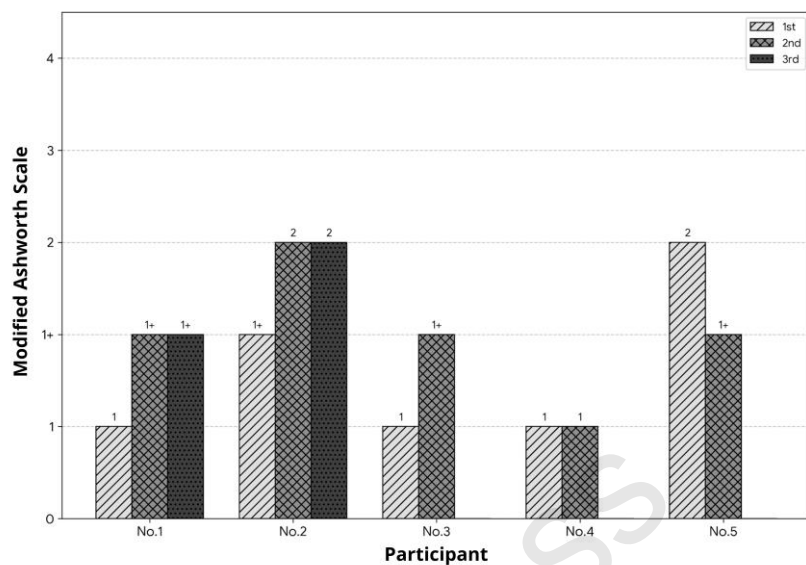


Figure 6. Spasticity of the Upper Extremity Assessed by the Modified Ashworth Scale

Discussion

In this preliminary cohort, early subacute ipsilesional MR presence was not associated with upper extremity recovery on the FMA-UE, and contralesional MT showed no association either. Instead, functional improvements across the FMA-UE, BBT, and SAFE scores at 3 and 6 months appeared more closely related to the patients' baseline clinical severity. Participants with moderate impairment demonstrated functional gains regardless of their MR or MT status, whereas those with severe impairment showed minimal to no functional increases. The more striking observations were longitudinal. Three of 4 patients who were MR-absent in the subacute phase developed a MR at approximately 4 to 5 months, 2 of whom achieved clinically meaningful motor gains, while a patient who remained persistently MR-absent on ipsilesional stimulation showed a response on contralesional stimulation of the affected hand at 6 months. Conversely, all participants improved in functional independence on the BI, regardless of their MR presence or absence. This universal gain likely reflects the successful training and application of compensation techniques using the unaffected limb, rather than true focal corticomotor recovery. Taken together, these observations suggest that corticomotor continuity behaves less like a fixed prognostic substrate and more like a dynamic feature that can reemerge over time.

Most TMS prognostic evidence is built on assessment within the first week, on MR-positive patients, and on focal figure-of-8 stimulation with electromyographic recording, and severely affected, MR-absent patients are routinely underrepresented or excluded.⁴ The present study deliberately examined this understudied group within the subacute window using an observational movement method and a broad-field parabolic coil suited to routine clinical practice, and it documented late MR emergence serially, including via contralesional stimulation. However, few studies have characterized corticomotor continuity specifically in severely impaired subacute patients assessed in this pragmatic way.

The absence of an early subacute association is directionally consistent with reports that TMS prognostic accuracy is highest when assessment is early and declines at later time points.⁸⁻¹⁰ The late reemergence of responses accords with prior observations of MEP reemergence up to 12 months poststroke¹⁹ and with the timescale of remyelination and resolution of perilesional edema.¹¹ That severely affected, initially MR-absent patients nonetheless recovered is consistent with earlier work showing meaningful recovery in severely impaired patients, particularly with sensory-led training.¹³ What does not fit is the simple binary expectation that early MR absence marks a fixed poor-prognosis deficit. These observations favour a more nuanced, time-dependent reading of corticomotor continuity in the subacute phase.

Two nonmutually exclusive explanations are plausible. The first is biological. An early MR may index surviving corticospinal substrate,²⁰ whereas a subacute or later MR is increasingly shaped by reorganization. Corticospinal projections arise not only from the precentral strip but also from premotor, supplementary motor, somatosensory, and posterior parietal cortices, and contralesional pathways may contribute drive to the paretic hand.^{11, 12} Recruitment distributed across these sources could reestablish a detectable response only gradually. The sensory-led rehabilitation routinely delivered in this study setting (Cognitive Sensory Motor Training Therapy) engages somatosensory and parietal systems that contribute to the corticospinal tract, offering a plausible, though here untested, route to such reorganization.^{12, 13} Additionally, the contralesional response in one persistently ipsilesional-absent patient is consistent with recruitment of alternative descending pathways. The second explanation is methodological. Detecting a response solely by observed movement is insensitive and likely overestimates MR absence, particularly in a cohort as impaired that in this study (average baseline FMA-UE approximately 18 and BBT 0, despite some retained active finger flexion or extension on MRC testing). With a stimulation ceiling of 60% MSO, a response that was present but high-threshold early could become detectable later as the threshold fell. Although this 60% MSO ceiling was set primarily to ensure patient safety and tolerability, researchers actively facilitated MR detection by incorporating active muscle contraction or motor imagery. These techniques are clinically established to enhance cortical excitability, thereby assisting in identifying thresholds in patients who might otherwise be categorized as MR-absent.

The findings must be read as descriptive and hypothesis-generating. The sample was very small, with only 5 participants completing follow-up and a single MR-positive patient at baseline, precluding meaningful between-group comparison or inference, and recruitment fell well short of the powered target. Crucially, the findings are based on a very small, all-male sample from a single tertiary center with a specific stroke profile. Therefore, these observations cannot be generalized to the broader subacute stroke population. The observational method, used without electromyography or neuronavigation, reduces sensitivity and reliability, and subacute TMS measures are known to have limited test-retest reliability even under more controlled conditions.^{11, 21} Rehabilitation was heterogeneous usual care that was not standardized or recorded per participant, including the sensory-led training discussed above, so no outcome can be attributed to any specific intervention. Notably, the 2 strongest responders were also the youngest participants and both received robotic-assisted therapy and rTMS, confounding age, intervention, and spontaneous plasticity. The timing of the initial assessment varied between 33 and 83 days, the study was single-center, and no structural imaging correlate of corticospinal integrity was obtained.

These observations caution against using early or subacute MR absence to ration rehabilitation or to set a low ceiling on expectations, since several severely affected, MR-absent patients improved. While MEPs assessed during the acute stroke phase are well-established predictors of functional recovery, the present findings suggest that the clinical utility of using observational MR and MT to predict functional recovery remains unclear. This lack of evident predictive value is largely attributable to the very small number of subjects in this cohort. The observational method is feasible in routine clinical settings that lack electromyography and neuronavigation, but its sensitivity limitations argue for cautious interpretation, particularly when a response is absent.

This study observed that, using the visual observation technique, a sizable portion of initially MR-absent patients showed a different response later. Such findings from this group of patients suggest that, in order to detect a possible correlation between the subacute single-pulse TMS MR and functional recovery, an even larger sample size than the initially calculated will likely be required. This renders the originally planned cross-sectional approach less feasible for routine practice.

Given the dynamic nature of the subacute MR and the impractically large sample this would demand, these preliminary findings led to redirection rather than the continuation of the originally planned cross-sectional correlation study. This study proposes instead to use serial TMS within individual patients as a monitoring tool, and to establish the temporal relationship between the change in the evoked MR and the change in functional performance, specifically which of the 2 reaches a plateau first. Knowing this order would let serial TMS be used to monitor progress and to set realistic expectations. When one measure plateaus in a given patient, the clinician could judge whether further functional gain remains likely or whether recovery is approaching its ceiling and counsel the patient and plan rehabilitation accordingly. If the MR continues to evolve after functional performance has plateaued, latent corticomotor capacity may remain and warrant continued corticomotor-targeted training.²² If functional gains continue after the MR has plateaued, those later gains are more likely to reflect compensation than corticomotor recovery. If both plateau together, serial TMS may serve as an objective marker that corticomotor recovery has saturated.

Conclusions

In this preliminary cohort, early subacute corticomotor pathway continuity was not clearly associated with upper extremity recovery, and the early absence of a MR should not be used to limit rehabilitation. Serial assessment revealed late reemergence of corticomotor responses, suggesting that subacute corticomotor continuity is dynamic rather than fixed. Rather than a large cross-sectional correlation study, future work should use serial, electromyography-based TMS within individual patients to track whether the MR or functional performance plateaus first, supporting progress monitoring and realistic expectation-setting.

Additional Information

Acknowledgments: The authors would like to thank the research team members of the Department of Rehabilitation Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand, for their helpful guidance and constructive comments on the methodology and discussion.

Ethics Approval: This study was approved by the Committee for Research of the Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand (MURA2023/641 on 31 August 2023).

Clinical Trial Consideration: This study does not report on a clinical trial.

Financial Support: This study was supported by the Research Fund and Data Analysis Unit, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand (RF_67043, Navan Chevasutho).

Conflict of Interest: The authors declare no conflict of interest.

Declaration of AI Assistance: The authors utilized large language models (Gemini and Claude) to assist in the English language editing of this manuscript. The final content was critically reviewed and approved by all authors, who take full responsibility for the accuracy, integrity, and originality of the work.

Author Contributions:

Conceptualization: Navan Chevasutho, Poramed Chayaratanasin

Formal Analysis: Navan Chevasutho, Poramed Chayaratanasin

Funding Acquisition: Navan Chevasutho

Investigation: Peerada Eurchedkul

Methodology: Navan Chevasutho, Poramed Chayaratanasin

Resources: Navan Chevasutho, Peerada Eurchedkul

Visualization: Navan Chevasutho, Poramed Chayaratanasin

Writing – Original Draft: Chevasutho, Poramed Chayaratanasin

Writing – Review & Editing: Peerada Eurchedkul

References

1. Luke C, Dodd KJ, Brock K. Outcomes of the Bobath concept on upper limb recovery following stroke. *Clin Rehabil.* 2004;18(8):888-898. doi:10.1191/0269215504cr793oa
2. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. *Lancet.* 2011;377(9778):1693-1702. doi:10.1016/S0140-6736(11)60325-5
3. Krakauer JW. Motor learning: its relevance to stroke recovery and neurorehabilitation. *Curr Opin Neurol.* 2006;19(1):84-90. doi:10.1097/01.wco.0000200544.29915.cc
4. Karatzetzou S, Tsiptsios D, Terzoudi A, Aggeloussis N, Vadikolias K. Transcranial magnetic stimulation implementation on stroke prognosis. *Neurol Sci.* 2022;43(2):873-888. doi:10.1007/s10072-021-05791-1
5. Chen SY, Winstein CJ. A systematic review of voluntary arm recovery in hemiparetic stroke: critical predictors for meaningful outcomes using the international classification of functioning, disability, and health. *J Neurol Phys Ther.* 2009;33(1):2-13. doi:10.1097/NPT.0b013e318198a010

6. Bembenek JP, Kurczyk K, Karli Nski M, Czlonkowska A. The prognostic value of motor-evoked potentials in motor recovery and functional outcome after stroke - a systematic review of the literature. *Funct Neurol*. 2012;27(2):79-84.
7. Jo JY, Lee A, Kim MS, et al. Prediction of motor recovery using quantitative parameters of motor evoked potential in patients with stroke. *Ann Rehabil Med*. 2016;40(5):806-815. doi:10.5535/arm.2016.40.5.806
8. Stinear CM, Byblow WD, Ackerley SJ, Smith MC, Borges VM, Barber PA. PREP2: a biomarker-based algorithm for predicting upper limb function after stroke. *Ann Clin Transl Neurol*. 2017;4(11):811-820. doi:10.1002/acn3.488
9. Lundquist CB, Nielsen JF, Arguissain FG, Brunner IC. Accuracy of the upper limb prediction algorithm PREP2 applied 2 weeks poststroke: a prospective longitudinal study. *Neurorehabil Neural Repair*. 2021;35(1):68-78. doi:10.1177/1545968320971763
10. Swayne OB, Rothwell JC, Ward NS, Greenwood RJ. Stages of motor output reorganization after hemispheric stroke suggested by longitudinal studies of cortical physiology. *Cereb Cortex*. 2008;18(8):1909-1922. doi:10.1093/cercor/bhm218
11. Shanks MJ, Byblow WD. Corticomotor pathway function and recovery after stroke: a look back and a way forward. *J Physiol*. 2025;603(3):651-662. doi:10.1113/JP285562
12. Lemon RN. Descending pathways in motor control. *Annu Rev Neurosci*. 2008;31:195-218. doi:10.1146/annurev.neuro.31.060407.125547
13. Chanubol R, Wongphaet P, Chavanich N, et al. A randomized controlled trial of cognitive sensory motor training therapy on the recovery of arm function in acute stroke patients. *Clin Rehabil*. 2012;26(12):1096-1104. doi:10.1177/0269215512444631
14. Varnava A, Stokes MG, Chambers CD. Reliability of the 'observation of movement' method for determining motor threshold using transcranial magnetic stimulation. *J Neurosci Methods*. 2011;201(2):327-332. doi:10.1016/j.jneumeth.2011.08.016
15. Jitsakulchaidej P, Wivatvongvana P, Kitisak K. Normal parameters for diagnostic transcranial magnetic stimulation using a parabolic coil with biphasic pulse stimulation. *BMC Neurol*. 2022;22(1):510. doi:10.1186/s12883-022-02977-8
16. Woytowicz EJ, Rietschel JC, Goodman RN, et al. Determining levels of upper extremity movement impairment by applying a cluster analysis to the Fugl-Meyer assessment of the upper extremity in chronic stroke. *Arch Phys Med Rehabil*. 2017;98(3):456-462. doi:10.1016/j.apmr.2016.06.023
17. Oliveira CS, Almeida CS, Freitas LC, et al. Use of the box and block test for the evaluation of manual dexterity in individuals with central nervous system disorders: a systematic review. *Man Ther Posturology Rehabil J*. 2016;14:436. doi:10.17784/mtprehabjournal.2016.14.436
18. Sinoff G, Ore L. The Barthel activities of daily living index: self-reporting versus actual performance in the old-old (> or = 75 years). *J Am Geriatr Soc*. 1997;45(7):832-836. doi:10.1111/j.1532-5415.1997.tb01510.x
19. Misra UK, Kalita J. Motor evoked potential changes in ischaemic stroke depend on stroke location. *J Neurol Sci*. 1995;134(1-2):67-72. doi:10.1016/0022-510x(95)00216-4
20. Kumar P, Prasad M, Das A, et al. Utility of transcranial magnetic stimulation and diffusion tensor imaging for prediction of upper-limb motor recovery in acute ischemic stroke patients. *Ann Indian Acad Neurol*. 2022;25(1):54-59. doi:10.4103/aian.aian_254_21
21. Collins KC, Clark AB, Pomeroy VM, Kennedy NC. The test-retest reliability of non-navigated transcranial magnetic stimulation (TMS) measures of corticospinal pathway excitability early after stroke. *Disabil Rehabil*. 2024;46(26):6439-6446. doi:10.1080/09638288.2024.2337107
22. Milot MH, Spencer SJ, Chan V, et al. Corticospinal excitability as a predictor of functional gains at the affected upper limb following robotic training in chronic stroke survivors. *Neurorehabil Neural Repair*. 2014;28(9):819-827. doi:10.1177/1545968314527351